REMARKS

1. The Amendments and the Support Therefor

Two claims (34 and 35) have been canceled, one new claim (50) has been added, and claims 20, 36, 37, 48, and 49 have been amended to leave claims 20-33 and 36-50 in the application. No new matter has been added by the amendments or new claims, wherein:

- *Independent claim 20* has been amended to incorporate claims 34 and 35, which are addressed to the metallic intermediate layer (shown, for example, at reference numeral 3 in Fig. 1 and discussed at page 7 lines 15-22);
- *Independent claims 48 and 49* and *dependent claim 50* are similarly amended to recite the intermediate layer noted above.

Independent claims 20, 48, and 49, and thus all dependent claims, are submitted to be allowable for at least the following reasons.

As noted in the Office Action at pages 6 and 9, the cited primary references (U.S. Patent 5,024,670 to *Smith et al.* and U.S. Patent 5,686,176 to *Adam et al.*) do not show an intermediate layer as recited in claims 34-37. U.S. Patent 5,229,198 to *Schroeder* is then cited in the Office Action for suggesting this feature:

> Regarding claim 34 - 37 and 46, *Smith* is silent to an intermediate layer being formed. However, *Schroeder* teaches that a thin layer of bronze may be formed between the mesh and the overlay and/or between the mesh and the backing in order to provide an increased surface area and the microscopic voids are able to increase the locking of the resin (col. 3, ln. 45-50). It would have been obvious to one of ordinary skill in the art to have formed a thin layer such as the bronze layer of *Schroeder* in order to increased the locking of the overlay to the composite.

(Bottom of page 6 of Office Action; see also top of page 9 of Office Action for similar comments regarding U.S. Patent 5,686,176 to *Adam et al.*) Looking to the cited passage of *Schroeder* (at column 3 lines 45-50):

> Before the interstices are filled with resin *[i.e., before the overlay layer is added]*, a thin layer of bronze powder may be sintered to the wire mesh screen *[the outer reinforcement material]* and/or to the backing sheet *[the inner support]*. The increased surface area and the microscopic voids or pockets provided by the sintered powder increase the locking action of the resin.

Thus, *Schroeder* suggests the addition of an intermediate layer which is "rough" (which has voids/pockets and increased surface area), for the purpose of increasing the adhesion of the added

overlay layer. To form this rough intermediate layer, *Schroeder* sinters the intermediate layer (the bronze powder) to the outer reinforcement material (wire mesh screen) and/or to the inner support (backing sheet). It is well known that sintering results in rough materials which bear numerous pores/cavities; see, e.g., the attached excerpt from *Kalpakjian, S.*, Manufacturing Processes for Engineering Materials (noting at page 659 how sintering can result in a "network of interconnected pores or cavities").

In contrast, the present independent claims 20, 48, and 49 have been amended to recite a galvanized and/or plated intermediate layer, which is smooth (unlike *Schroeder*'s rough sintered layer): galvanized and/or plated layers, being electrochemical coatings as opposed to fused powders (as with sintering), will *fill in* voids in the material to which they adhere, rather than increasing such voids (or they will at the very least simply reflect any voids in the adhered material, rather than enhancing such voids). Thus, such a layer does not fulfill *Schroeder*'s objectives of increasing surface roughness, and therefore increase adhesion of the overlay layer.

We therefore submit that *Schroeder*, when considered fairly and objectively for all that it teaches, in no way suggests the modification of forming a galvanized/plated (and thus smooth) intermediate layer: it would not enhance surface roughness (as sought by *Schroeder*), and would provide no apparent benefit, while at the same time such an intermediate layer would increase the time and cost of manufacture. As noted by MPEP 2143, for the claimed arrangement to be obvious, "there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. . . . The teaching or suggestion to make the claimed combination . . . . must both be found in the prior art, not in applicant's disclosure." Here, since there is no motivation for one of ordinary skill to form a smooth galvanized and/or plated intermediate layer as claimed, we submit that independent claims 20, 48, and 49 (and thus all dependent claims) are

in condition for allowance. If the Office nevertheless believes *Schroeder* or another reference of record to suggest any advantage to the formation of a smooth intermediate layer, it is respectfully requested that the Office identify with particularity the location and content of the alleged suggestion.[1]

If any questions regarding the application arise, please contact the undersigned attorney. Telephone calls related to this application are welcomed and encouraged. The Commissioner is authorized to charge any fees or credit any overpayments relating to this application to deposit account number 18-2055.

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ATTACHMENTS:

- *Kalpakjian, S.*, Manufacturing Processes for Engineering Materials, Addison-Wesley, Pp. 656-659
- PTO-2038 ($450)

[1] 37 CFR §1.104(c)(2); "when the PTO asserts that there is an explicit or implicit teaching or suggestion in the prior art, it must indicate where such a teaching or suggestion appears in the reference," *In re Rijckaert*, 28 USPQ2d 1955, 1957 (Fed. Cir. 1993); "When relying on numerous references or a modification of prior art, it is incumbent upon the examiner to identify some suggestion to combine references or make the modification," *In re Mayne*, 41 USPQ2d 1451, 1454 (Fed. Cir. 1997).

KALPAKJIAN, S., MANUFACTURING PROCESSES FOR ENGINEERING MATERIALS (ADDISON WESLEY)
Pp. 656-659

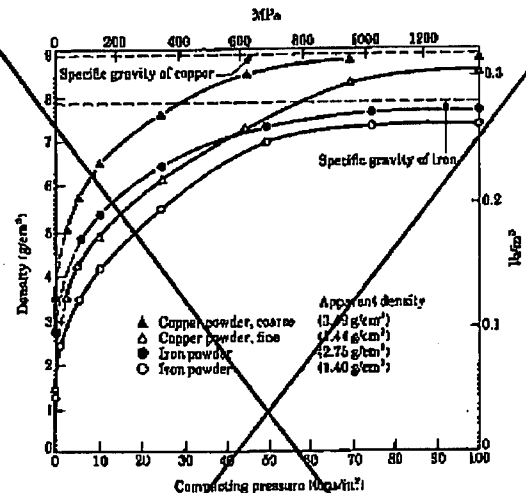

FIGURE 11.5 Density of iron and copper powders as a function of compacting pressure. Note that the increase in density stabilizes, approaching the density of the bulk metal, after a certain pressure is reached. Density has a major influence on the mechanical and physical properties of powder metallurgy products. See also Fig. 11.7. *Source:* After F. V. Lenel.

with a hardness of 60 to 64 HRC. Tungsten carbide dies are used for more severe applications. Punches are generally made of similar materials. (See Table 6.4.)

Close control of die and punch dimensions and tolerances is essential for proper compaction and die life. For instance, too large a clearance between the punch and the die will allow the metal powder to enter the gap and interfere with the operation and also will result in eccentricity. Diametral clearances are generally less than 0.001 in. (25 μm). Die and punch surfaces must be lapped or polished (in the direction of tool movements) for improved die life and overall performance.

11.2.4 SINTERING

Sintering is the process whereby the compacted metal powder is heated in a controlled-atmosphere furnace to a temperature just below its melting point, but sufficiently high to allow *bonding* of the individual particles. Prior to sintering, the compact is quite brittle and its strength (*green strength*) is low. In order to facilitate handling, compacts

may be *presintered* by heating them to a temperature lower than the normal temperature for final sintering.

The nature and strength of the bond between the particles, and hence of the sintered compact, depend on the mechanisms of:

a. Diffusion,
b. Plastic flow,
c. Evaporation of volatile materials in the compact,
d. Recrystallization,
e. Grain growth,
f. Shrinkage.

The principal governing variables in sintering are temperature, time, and the atmosphere. Sintering temperatures are generally within 70 to 90% of the melting point, and sintering times at these temperatures range from a minimum of about 10 minutes for iron and copper alloys to as much as eight hours for tungsten and tantalum (Table 11.3). Continuous sintering furnaces are used for most production today. These furnaces have three chambers:

a. Burn-off chamber to volatilize the lubricants in the green compact in order to improve bond strength,
b. High-temperature chamber for sintering, and
c. Cooling chamber.

TABLE 11.3
SINTERING TEMPERATURE AND TIME FOR VARIOUS METALS

MATERIAL	TEMPERATURE °F	TEMPERATURE °C	TIME, MIN.
Copper, brass, and bronze	1400–1650	760–900	10–45
Iron and iron-graphite	1850–2100	1000–1150	8–45
Nickel	1850–2100	1000–1150	30–45
Stainless steels	2000–2350	1100–1290	30–60
Alnico alloys (for permanent magnets)	2200–2375	1200–1300	120–150
Ferrites	2200–2700	1200–1500	10–600
Tungsten carbide	2600–2700	1430–1500	20–30
Molybdenum	3750	2050	120
Tungsten	4250	2350	480
Tantalum	4350	2400	480

Furnaces may be batch-type or continuous furnaces, with a variety of features, for high-production runs. The purposes of controlling the atmosphere during sintering are to:

a. Control the carburization and decarburization of iron and iron-base compacts, and
b. Reduce oxides or to prevent oxidation of compacts.

An oxygen-free atmosphere is thus essential for sintering. Although a vacuum is used mainly for refractory metal alloys and stainless steels, the gases most commonly used with a variety of other metals are hydrogen, dissociated or burned ammonia, and exothermic or endothermic-type atmosphere. Proper control of the atmosphere is essential for successful sintering and to obtain optimal properties.

Mechanisms of Sintering

Sintering mechanisms are complex and depend on the composition of metal particles, as well as processing parameters. As temperature increases, two adjacent particles begin to form a bond by diffusion (*solid-state bonding*) (Fig. 11.6a). As a result, the strength, ductility, and thermal and electrical conductivities of the compact increase, as well as its density. This mechanism leads to shrinkage of the compact.

If the two particles are of different metals, alloying can take place at the interface. It is also possible for one of the particles to be of a lower-melting-point metal than the other. In that case, the particle may melt and, because of surface tension, the liquid

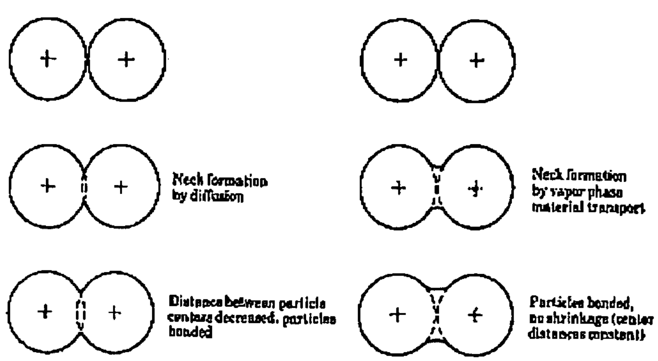

FIGURE 11.6 Schematic illustration of two mechanisms for sintering metal powders. (a) Solid-state material transport. (b) Liquid-phase material transport. Sintering is the process of bonding adjacent metal powders by heat. See also Table 11.3.

metal surrounds the higher-melting-point solid particle (Fig. 11.6b). This is known as *liquid-phase sintering*. An example is cobalt in tungsten carbide (see Section 8.10.4). In this way stronger and denser parts are obtained.

POROSITY

Depending on time, temperature, and processing history, different structures and porosities can be obtained in a sintered compact. This also depends on the extent of diffusion, recrystallization, and grain growth. Porosity cannot be completely eliminated because of the presence of voids during compaction and gases evolved during sintering. Porosity can be either a network of interconnected pores or cavities, or closed holes.

In addition to the commonly used furnace sintering, another method is *spark sintering*. In this process, which is still at an experimental stage, the loose metal powders are subjected to a high-energy discharge while in a graphite mold, heated by electrical current, and then compacted, all in one step. The rapid discharge strips any oxide coating (such as those on aluminum) or contaminants from the surfaces of the particles and thus encourages good bonding during compaction at elevated temperatures.

Typical examples of the effect of compacting pressure and density on the properties of sintered compacts are shown in Fig. 11.7. It can be seen that, as expected, strength, ductility, and electrical conductivity (because of the larger contact area between the particles) increase with increasing pressure and density. Such data are available in the literature to aid in designing P/M parts. (See also Section 11.9.1 on the effect of porosity on mechanical properties.)

11.2.5 FINISHING OPERATIONS

In order to further improve the properties of sintered powder-metallurgy products, or to give them special characteristics, several additional operations may be carried out. Among these are coining, sizing, forging, infiltration, and impregnation.

Coining, Sizing, and Forging

Coining and sizing are additional compacting operations carried out in presses. They are performed under high pressure and with very little deformation of the part. The purposes of these operations are to give final precise dimensions to the sintered part, and to improve its surface finish and strength by additional densification.

An important development is the use of preformed, sintered alloy-powder compacts, which are subsequently cold or hot forged to the desired final shapes in closed dies. These products have good surface finish and dimensional tolerances, with uniform and fine grain size and distribution, and a microstructure relatively free of grain-boundary segregation and precipitates. The superior properties obtained make this technology particularly suitable for making automotive and jet-engine parts that are highly stressed.

Impregnation

The inherent porosity of powder-metallurgy components (those with an interconnected network of porosity) can be utilized to impregnate them, either with a fluid